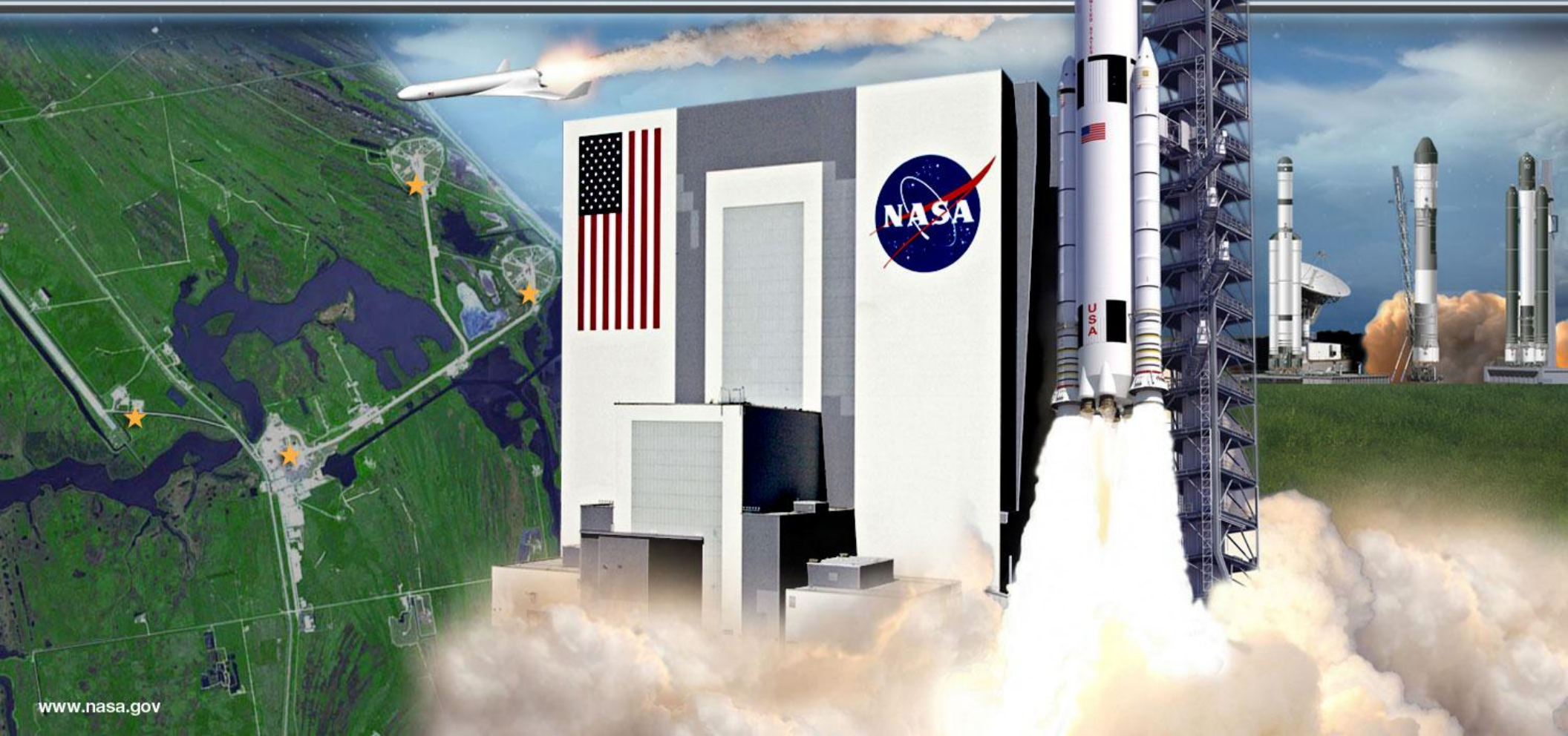
National Aeronautics and Space Administration

GROUND SYSTEMS
Development and Operations



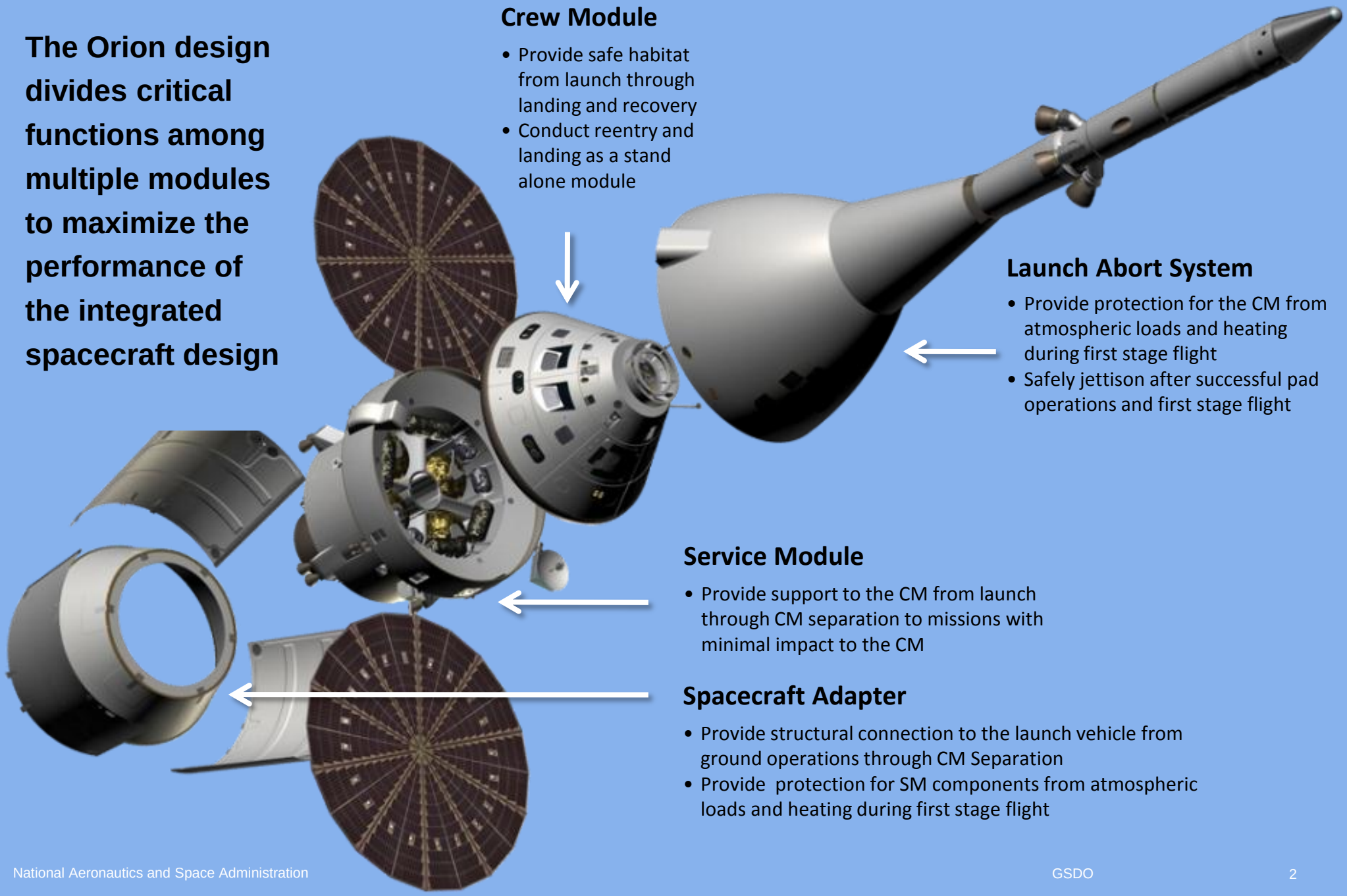
www.nasa.gov

Spacecraft Overview

The Orion design divides critical functions among multiple modules to maximize the performance of the integrated spacecraft design

Crew Module

- Provide safe habitat from launch through landing and recovery
- Conduct reentry and landing as a stand alone module



Launch Abort System

- Provide protection for the CM from atmospheric loads and heating during first stage flight
- Safely jettison after successful pad operations and first stage flight

Service Module

- Provide support to the CM from launch through CM separation to missions with minimal impact to the CM

Spacecraft Adapter

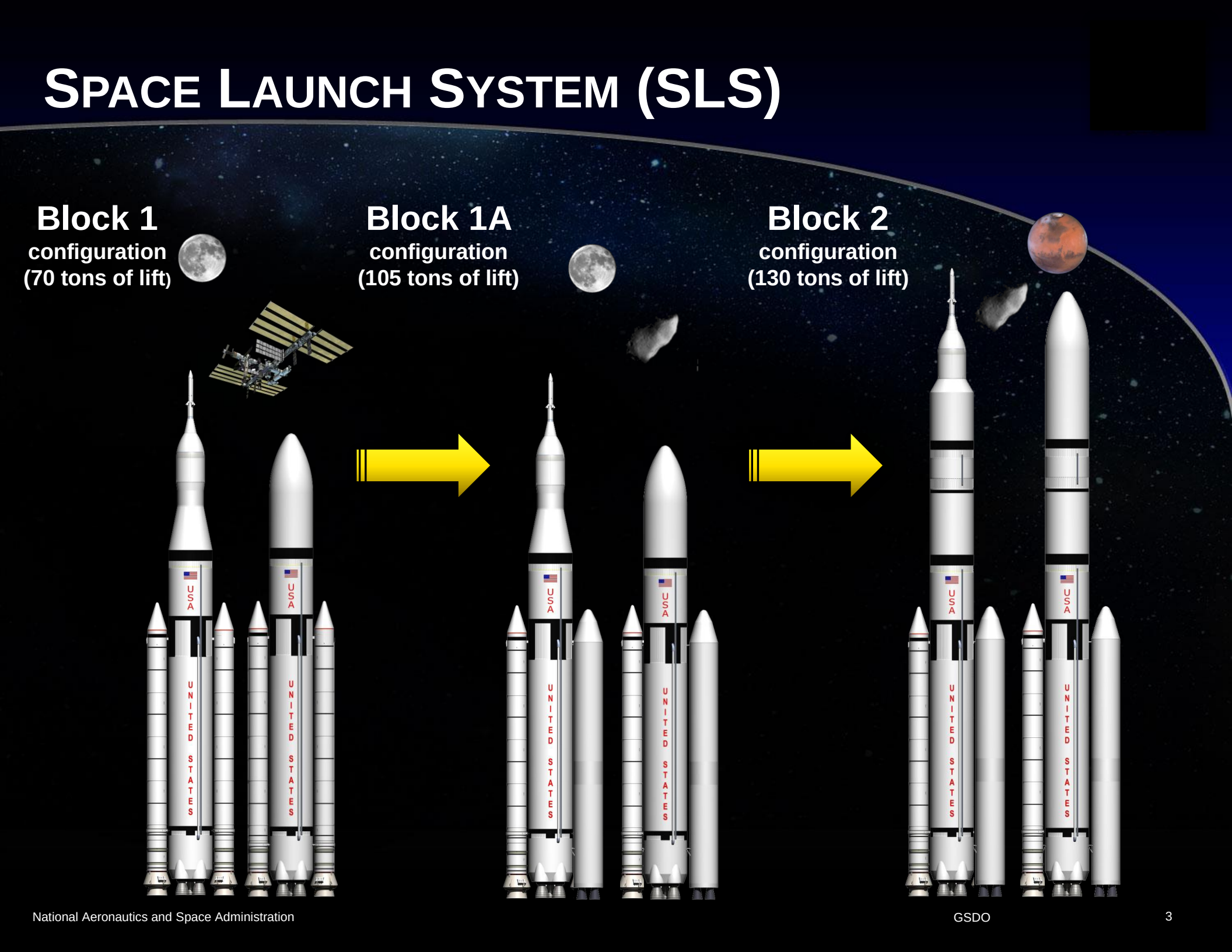
- Provide structural connection to the launch vehicle from ground operations through CM Separation
- Provide protection for SM components from atmospheric loads and heating during first stage flight

SPACE LAUNCH SYSTEM (SLS)

Block 1
configuration
(70 tons of lift)

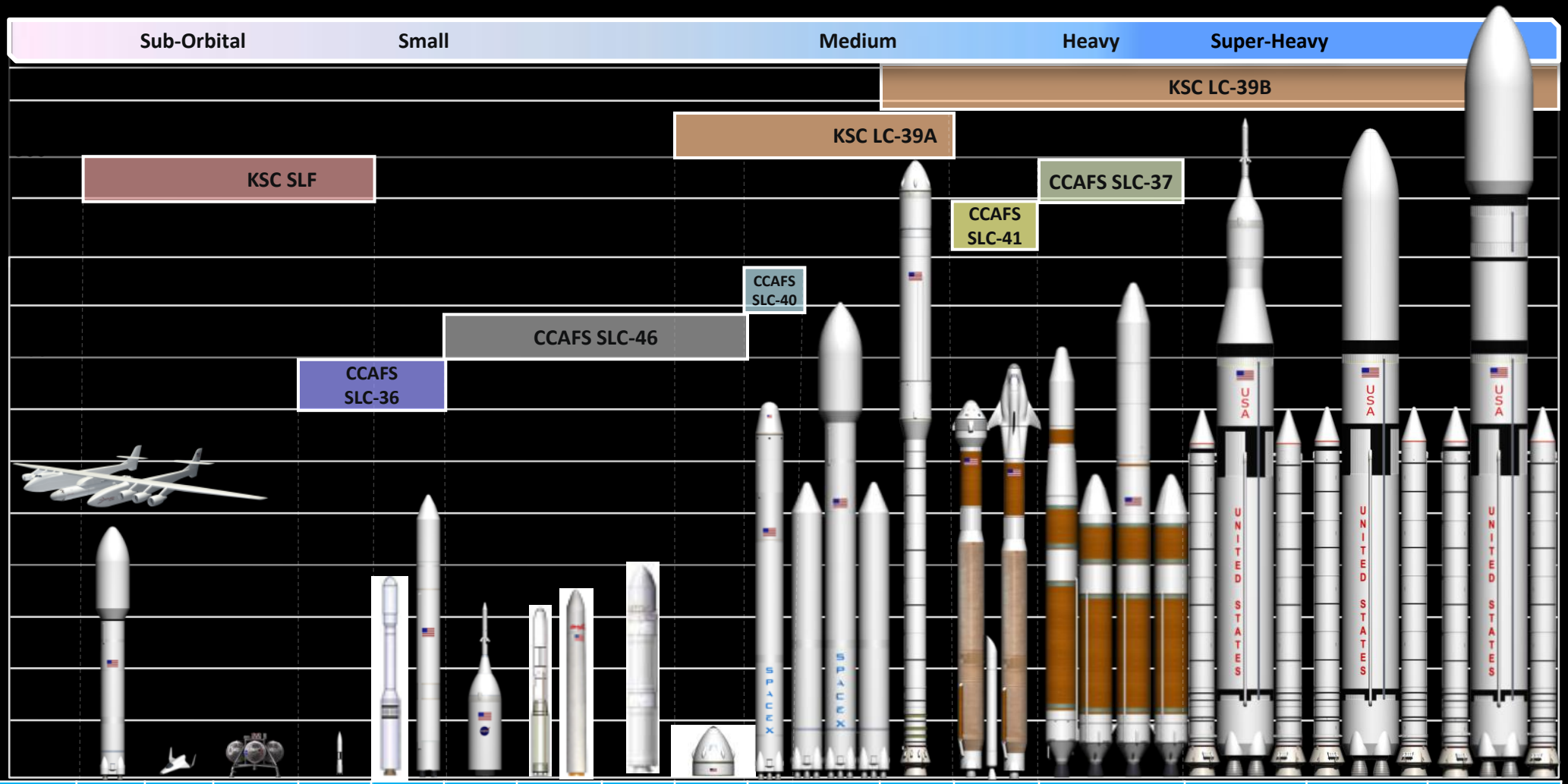
Block 1A
configuration
(105 tons of lift)

Block 2
configuration
(130 tons of lift)



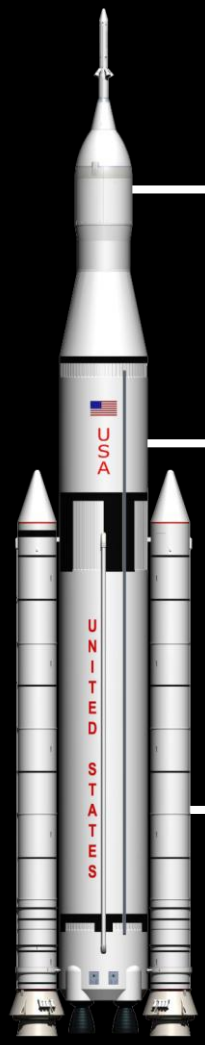
GROUND SYSTEMS
Development and Operations

THE ART OF THE POSSIBLE



	Strato-launch	XCOR Lynx	JSC Morpheus	Masten XA-1.0	Orbital Taurus I Antares	Orbital AA-2	Orbital MinotaurIV MinotaurV	ATK Athena II C	NESC MLAS FT-2	SpaceX Falcon 9 Falcon H	ATK Liberty	ULA Atlas V 412 Atlas V 402	ULA DeltaIV M Delta IV H	NASA SLS Block 1 Crewed	NASA SLS Block 1A Cargo	NASA SLS Block 2 Cargo

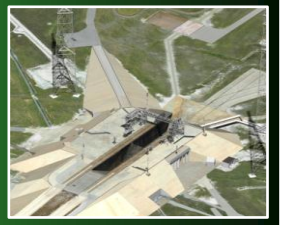
IF YOU HAVE A SPACECRAFT, WE HAVE A LAUNCH PAD.



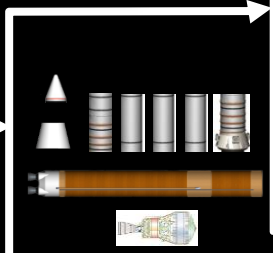
Offline Spacecraft Processing

Command, Control, Communications, and Range

Vehicle Integration and Launch



Core Stage Processing

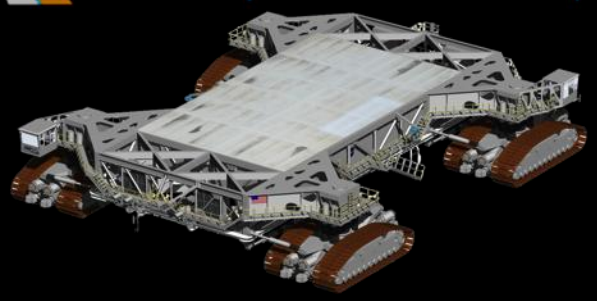


Offline Solid Rocket Booster Processing

Landing & Recovery

SLS / ORION(MPCV) CONCEPT OF OPERATIONS

GROUND SYSTEMS
Development and Operations



Move Operations with
Crawler Transporter

Launch Operations
at Pad 39B

Integration and Check-out
Operations in
Vehicle Assembly Building

Vehicle Access and Servicing
via Mobile Launcher

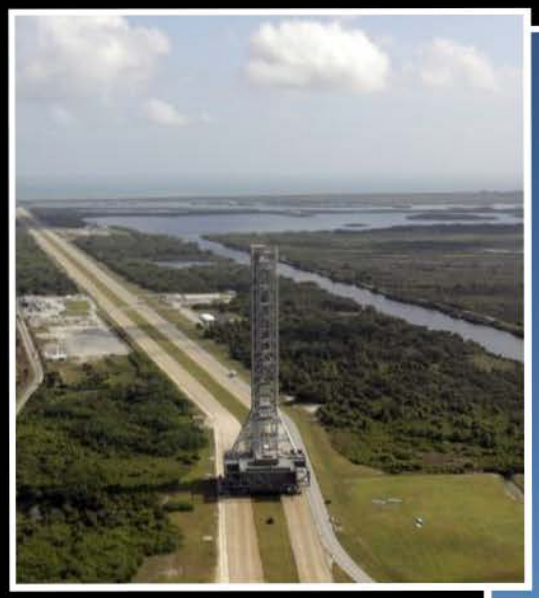
Planning and Studies to
Support Small Class Vehicles

VEHICLE INTEGRATION & LAUNCH CAPABILITIES

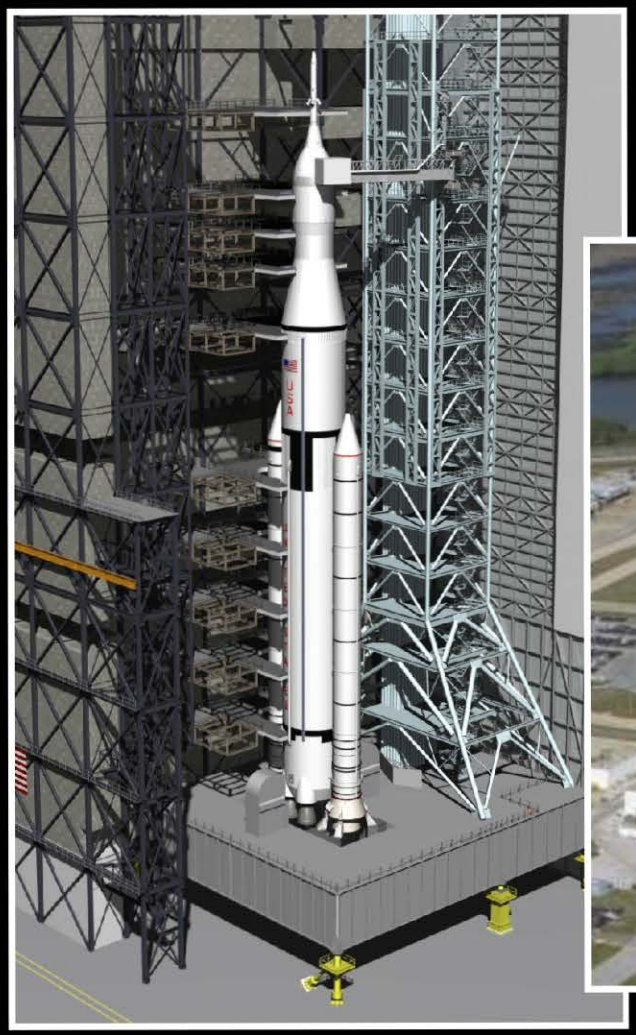
LAUNCH PAD 39A

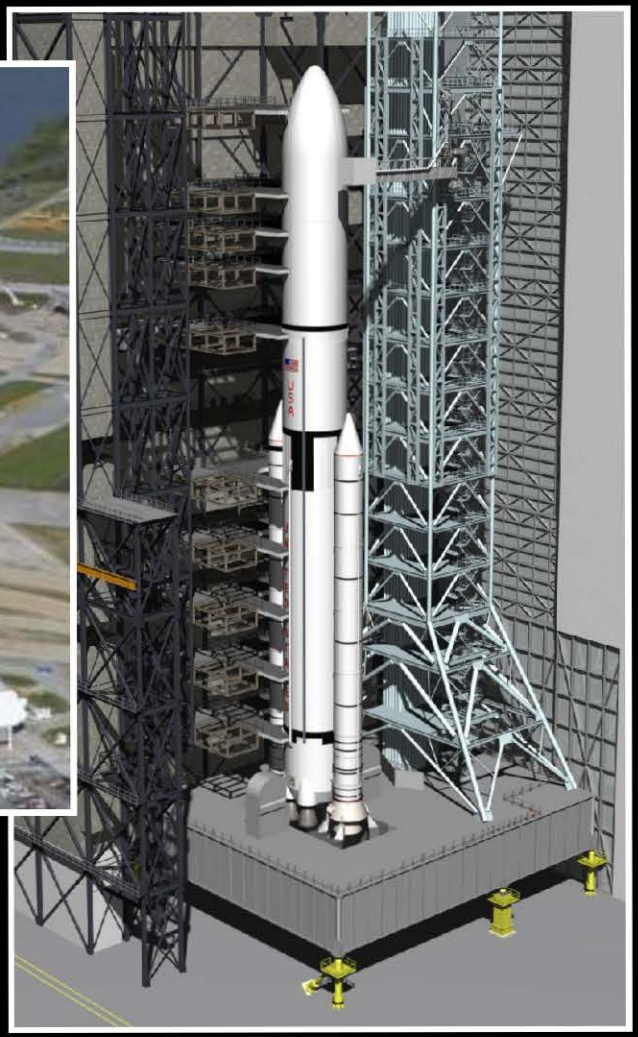
LAUNCH PAD 39B

LAUNCH PAD



MOBILE LAUNCHER





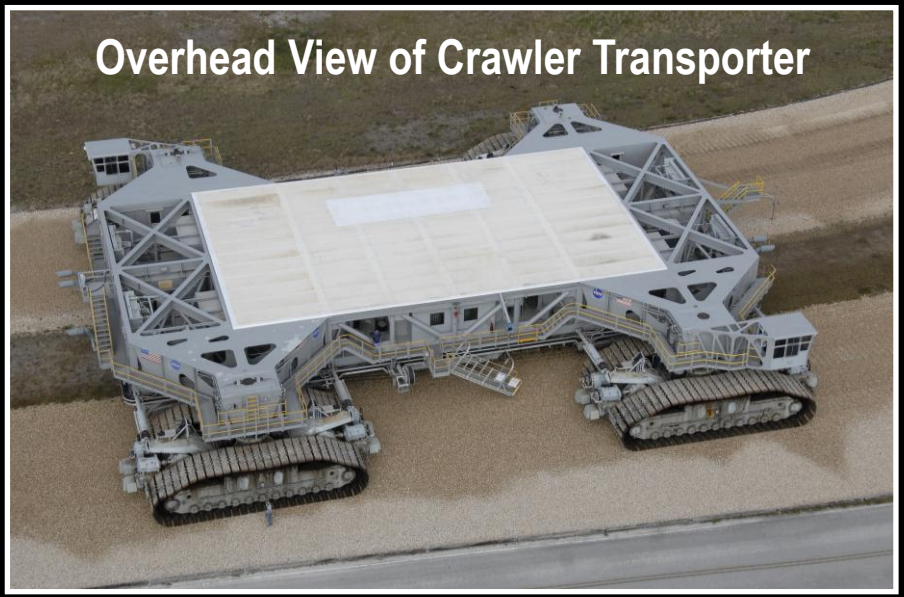
VEHICLE ASSEMBLY BUILDING

Crawler Transporter Near Launch Pad

Both Crawler Transporters at Crawler Yard

Crawler Transporter Upgrades

Overhead View of Crawler Transporter



CRAWLER TRANSPORTERS

MORPHEUS

SHUTTLE LANDING FACILITY

STARFIGHTERS

SMALL CLASS VEHICLES

GROUND SYSTEMS
Development and Operations

Environmental
& Infrastructure

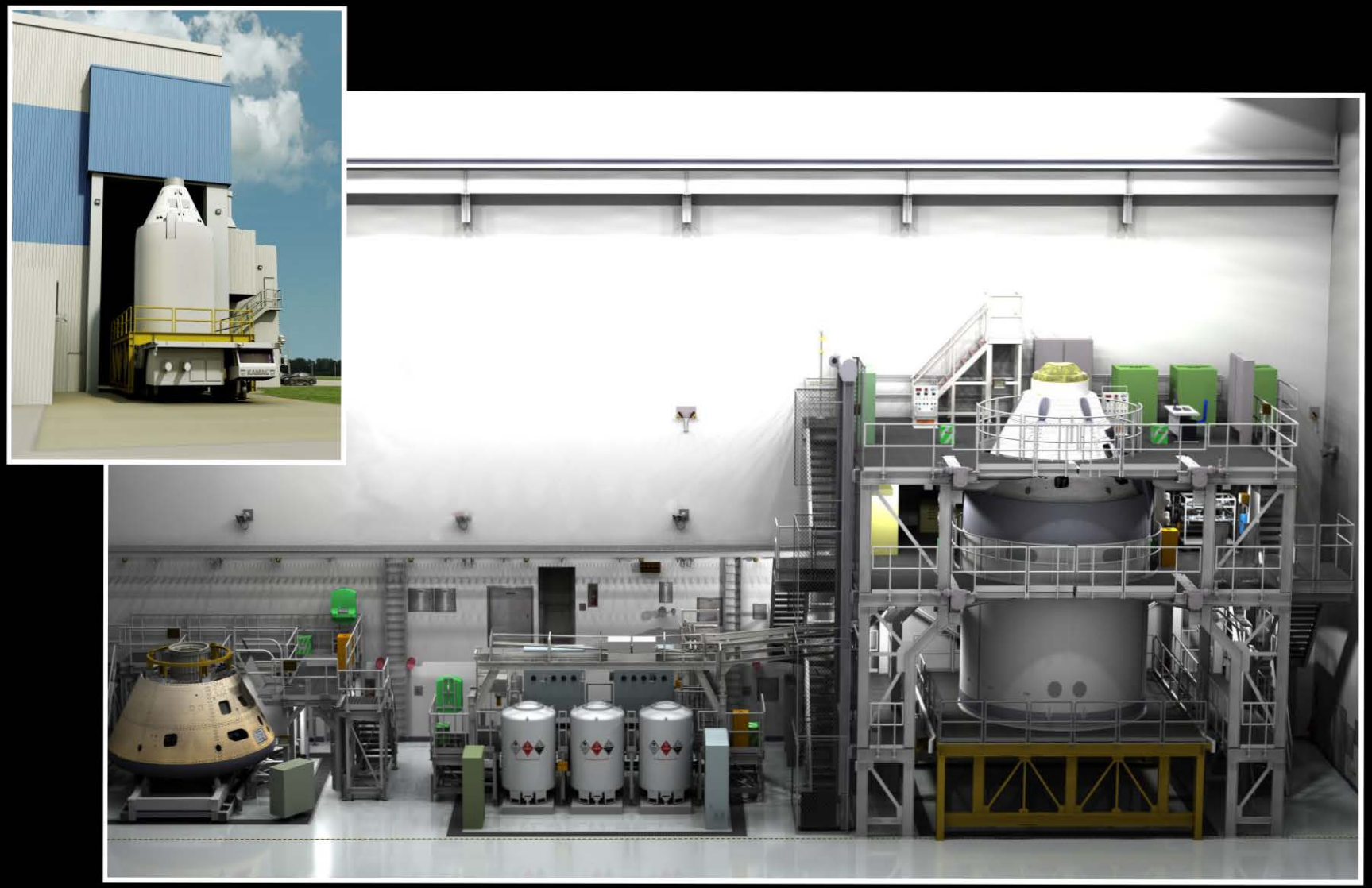
Spacecraft Offline Processing

Landing
& Recovery

Orion Production Ops

Launch Vehicle Offline Processing

OFFLINE PROCESSING & INFRASTRUCTURE CAPABILITIES



SPACECRAFT OFFLINE PROCESSING

LAUNCH VEHICLE OFFLINE PROCESSING

SPACECRAFT RECOVERY

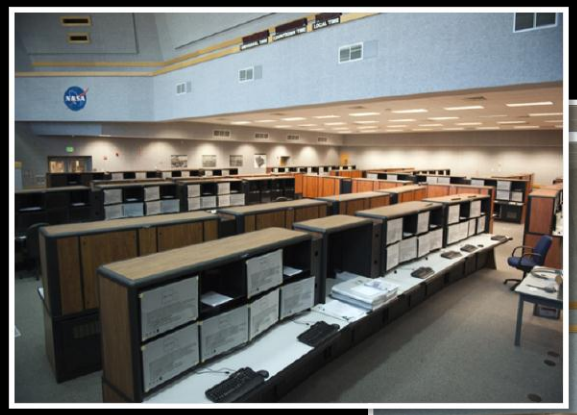
ENVIRONMENTAL

INFRASTRUCTURE

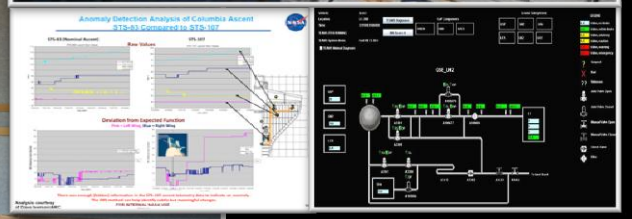
ENVIRONMENTAL / INFRASTRUCTURE

GROUND SYSTEMS
Development and Operations

End to End
Command and Control



Advanced Ground Systems
Maintenance



Communications Systems

Range Systems

COMMAND CONTROL COMMUNICATIONS & RANGE

GROUND SYSTEMS
Development and Operations

PROGRAM PROGRESS

2009	2010	2011	2012	2014
		GSDO Program Office Stand Up 15Jun MCR Board 30Nov	KDP-A 17JAN SRR/SDR Board 30AUG	EFT-1 Apr 2014

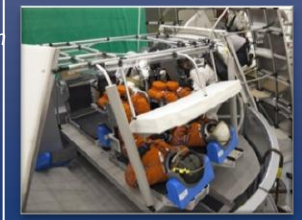
Program Progress

Lightning Protection Completed at Launch Pad 39B

Mobile Launcher Construction

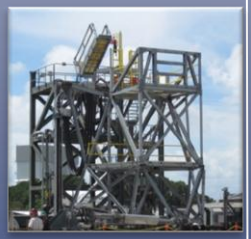
Service Structures Demolition at Launch Pad 39B

Orion Access Demonstration at Multi-Purpose Processing Facility (MPPF)



Firing Room 1 Complete at Launch Control Center (LCC)

Refurbishment Complete at Launch Equipment Test Facility (LETF)



Mobile Launcher Rollout Interface Test at LC-39B

Orion CM-2 Arrival at Multi-Purpose Processing Facility (MPPF)

Small Class Vehicle Testing at Shuttle Landing Facility (SLF)

Exploration Flight Test (EFT-1) Crew Module Recovery

DAWN OF A NEW ERA


NASA

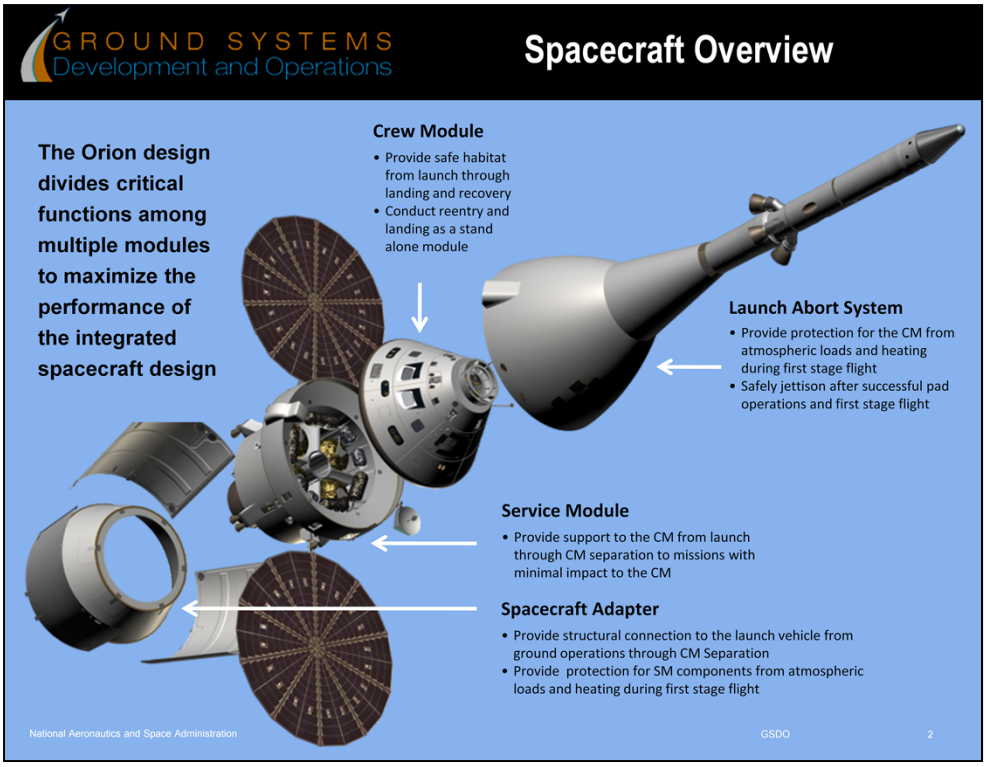
Key Points:

- The Ground Systems Development and Operations (GSDO) Program Vision: Launching the world's most powerful, advanced launch vehicles and spacecraft.
- The GSDO Program Mission: To be the driving force that transforms Kennedy Space Center (KSC) into the world's premier multi-user launch and landing spaceport.

Background Info:

- The GSDO Program was established to develop and use the complex equipment required to safely handle rockets and spacecraft during assembly, transport and launch.

    - For more info visit: http://www.nasa.gov/pdf/638587main_20120425_GSDO.pdf



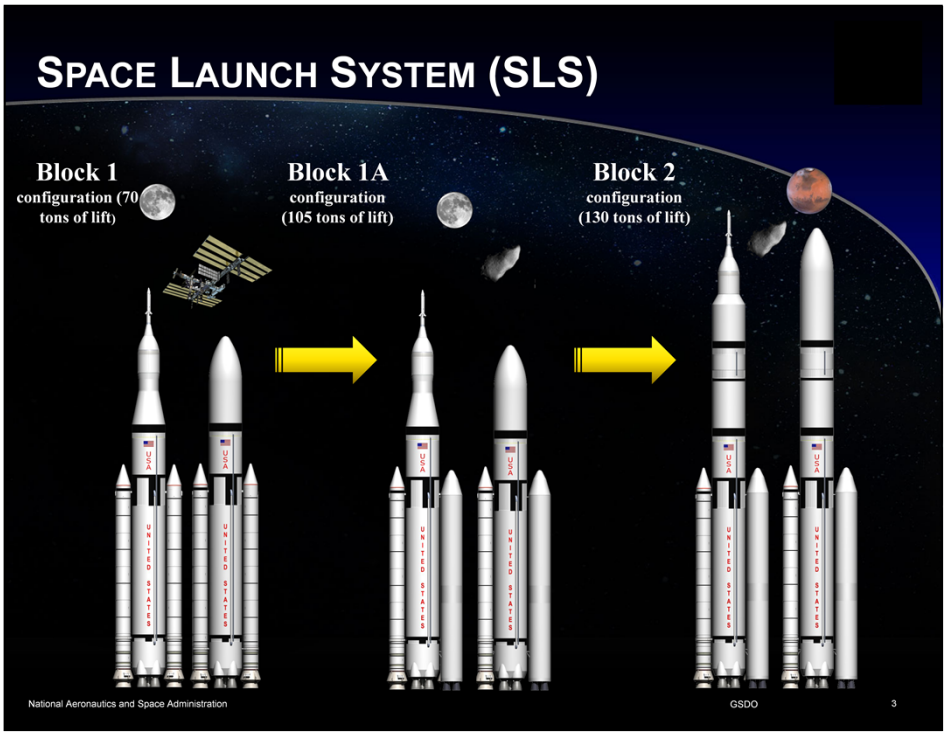
Key Points:

- The Orion Multi Purpose Crew Vehicle consists of a crew module, service module, spacecraft adapter to connect to the launch vehicle, and a launch abort system.
- The launch abort system has four rockets that lift the spacecraft away from the launch vehicle in the event of a problem.

Background Info:

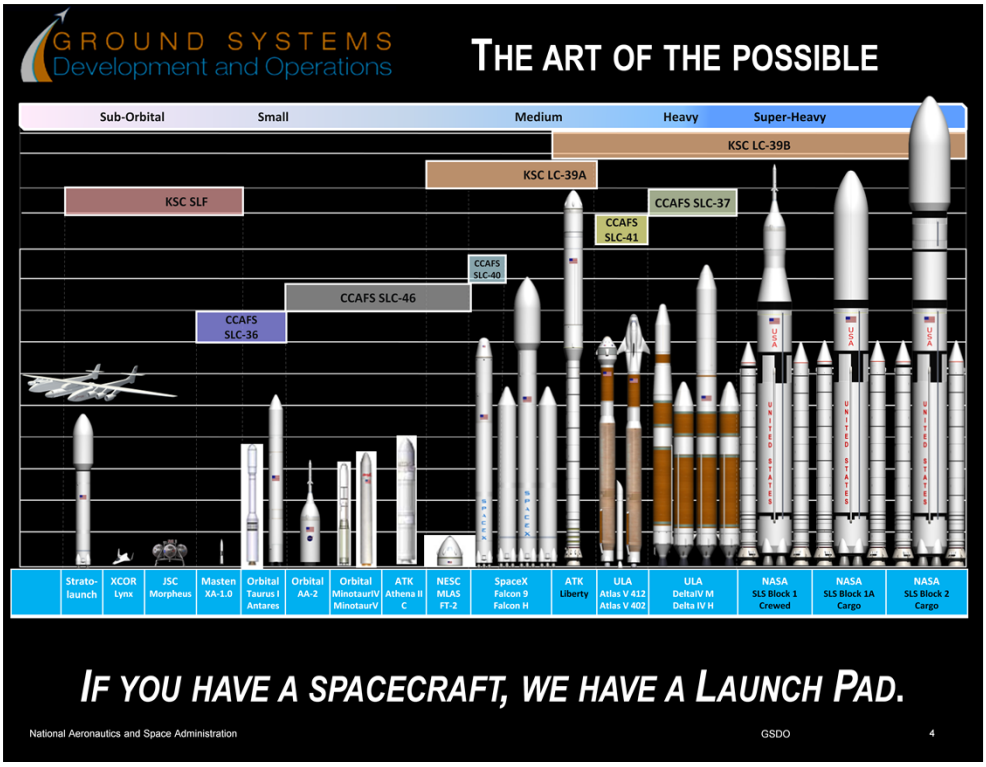
- The Launch Abort System can activate within milliseconds to pull the crew to safety and position the module for a safe landing.
- The Crew Module (CM) is capable of transporting four crew members beyond low Earth orbit.
- The Service Module when mated with the CM will provide water, oxygen and nitrogen to support the CM living environment, generates and stores power while on orbit, and provides primary thermal control.
- The Service Module also provides an in-space propulsion capability for orbital transfer, altitude control, and high altitude ascent aborts.
- The Spacecraft Adapter connects Orion to the Launch Vehicle.

    - For more information visit: http://www.nasa.gov/pdf/617408main_fs_2011-12-058-jsc_orion_quickfacts.pdf



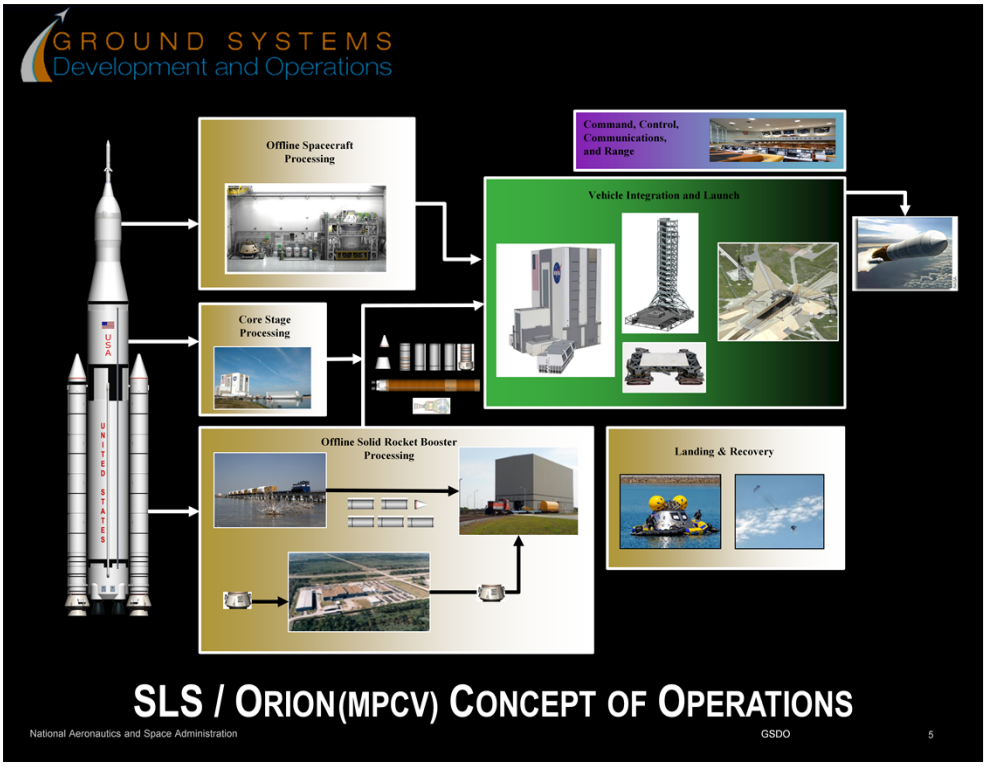
Key Points:

- The SLS will propel the Orion spacecraft or cargo to space.
- The SLS is intended to evolve from a 70 metric ton lift capacity vehicle, to 105 metric tons, and then to 130 metric tons.
- For each lift capacity shown here, the crewed configuration is shown on the left and the uncrewed (payload only) configuration is shown on the right.



Key Points:

- This chart shows potential launch vehicles and launch complexes (pad locations).
- LC-39 (Launch Complex 39) is capable of supporting Medium lift to Super-Heavy lift vehicles.

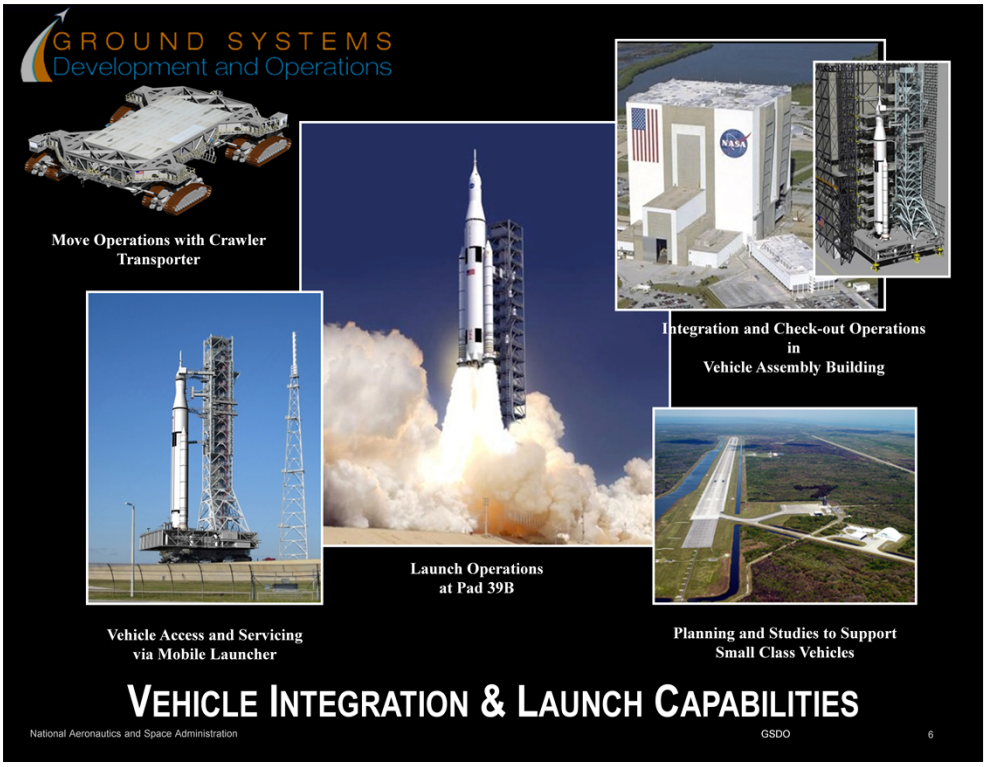


Key Points:

- This charts shows the current path that each part of the vehicle and spacecraft will take during build-up for launch.
- This includes the solid rocket boosters (SRBs), core stage, and Orion spacecraft.

Background Info:

- The term “offline” refers to operations that occur after arrival at KSC, but before the rocket/vehicle arrives at the launchpad.



Key Points:

- The **Vehicle Integration and Launch** team focuses on the equipment, management and operations required to safely connect a spacecraft with a rocket, move the launch vehicle to the launch pad and successfully send it into space.
- VIL includes vehicle integration, a mobile launcher platform to support build-up and launch, transportation to the pad via the crawler transporter, and a launch pad.
- Kennedy Space Center can perform planning and studies to support small class vehicles which intend to use the former Shuttle Landing Facility.

Key Points:

- GSDO currently has two launch pads.
- Launch Pad 39B is for SLS/MPCV and commercial users.
- Launch Pad 39A is available for other commercial vehicles.

Background Info:

- The Launch Complex 39 Pads A and B are roughly octagonal in shape. Each covers about 0.25-square-mile (0.65-square-kilometer) of land.
- The Pad A stand is 48 feet (14.6 meters) above sea level at its top, while the upper surface at Pad B is at an elevation of 55 feet (16.8 meters).
- The top of each pad measures 390 feet by 325 feet (119 meters by 99 meters).
- The pad base contains 52,000 cubic meters (68,000 cubic yards) of concrete.
- The three fixtures on the outskirt of Pad B are 600 ft. tall lightning towers, which will protect the rockets as they await launch.
- The flame trench is used to funnel sound waves and exhaust away from a launching rocket to prevent vibrations from damaging the craft during launch.

    - For more info check: http://www.nasa.gov/pdf/650785main_2012.05.16_Launch_Pad_39B.pdf

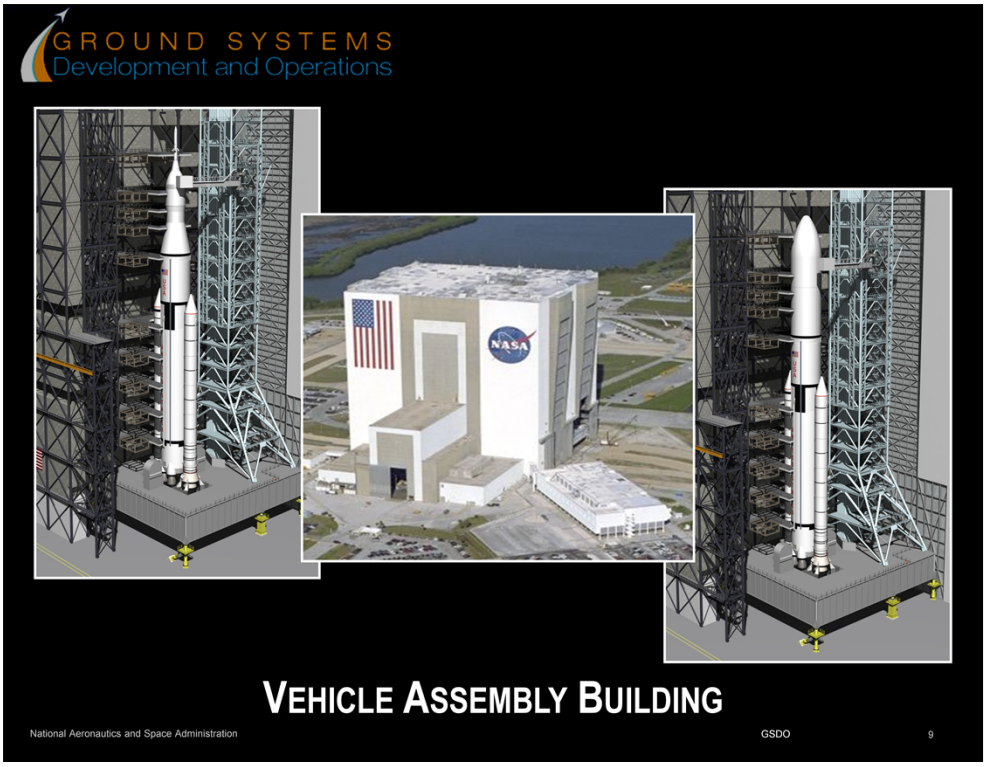
Key Points:

- The SLS Mobile Launcher is used for stacking the vehicle, transporting the vehicle to the pad, and as a launch platform.
- The Mobile Launcher (ML) consists of a base and a tower and provides all commodities to the vehicle prior to launch.

Background Info:

- The base of the ML measures 47 feet in height, 165 feet long and 135 feet wide.
- The tower itself is 40 feet square and 355 feet tall. Every 20 feet there is a floor level for personal access to vehicle and ground support equipment.
- The empty weight when outfitted with support equipment is about 10 million pounds.
    - Top left: ML traveling atop the Crawler to the Launchpad for testing.
    - Bottom left: The tower being constructed.
    - Top right: The bottom support of the tower being placed on the base.
    - Bottom right: The ML sitting at Pad B.

    - For more info visit: http://www.nasa.gov/pdf/621004main_2012.01.27_ML.pdf



Key Points:

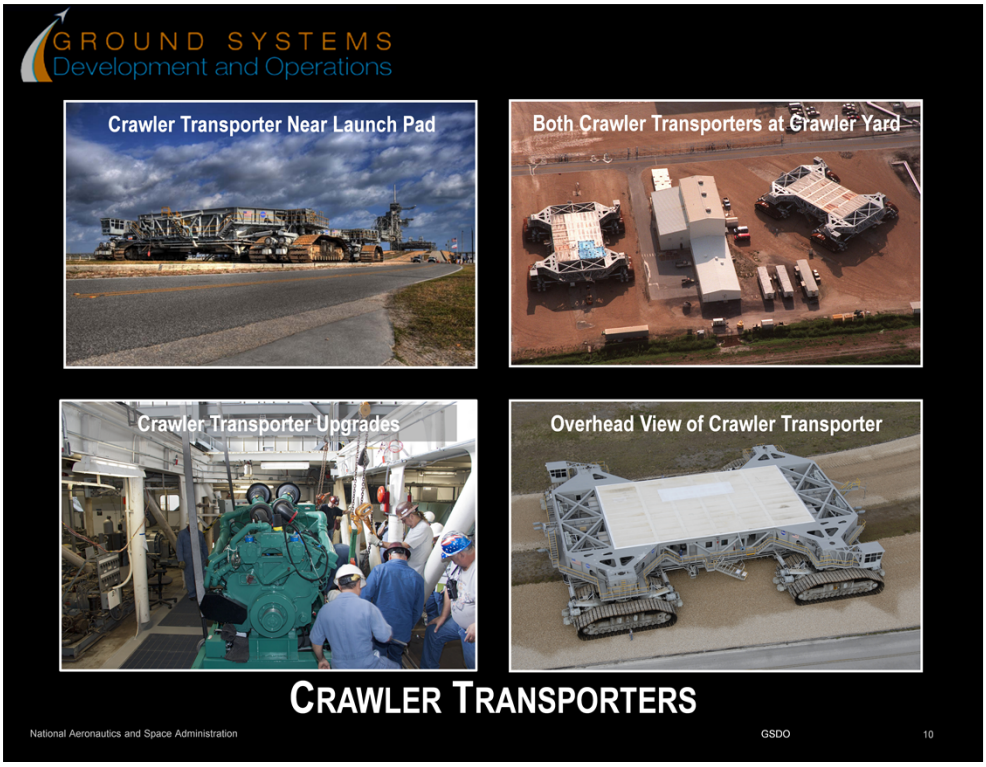
- The Vehicle Assembly Building (VAB) is the place where the vehicle is assembled on the ML, prior to rollout and launch.
- The VAB consists of four high-bays and multiple low-bays and at one time was the largest building in the world by volume.
- The figure on the left shows the SLS/MPCV in the high-bay, on the ML.
- The figure on the right shows the SLS with a cargo payload.

Background Info:

- The VAB is the largest single story building in the world.
- It remains the only building to assemble a rocket that carried humans to the surface of another world.
- There are four entries to the bays located inside the building, which are the four largest doors in the world (456 ft.).
- The VAB is made up of 65,000 cubic yards of concrete with a frame constructed from 98,590 tons of steel. The building itself stands atop a support base of 4,225 steel pilings driven 164 feet into bedrock.
- The VAB is home to the largest American flag, which spans 209 feet vertically by 110 feet wide.
    - The blue field is the size of a regulation basketball court.

    - Each star is 6 feet across and each stripe is 9 feet wide.
- Height: VAB – 160 meters (525 ft.) <--> Statue of Liberty - 93 meters (305 ft.)
- Volume: VAB – 3,665,013 cu meters (129,428,000 cu ft.) <--> Pentagon 2,181,117 cu meters (77,025,000 cu ft.).

    - For more info check: http://www.nasa.gov/pdf/650784main_2012.05.16_VAB.pdf



Key Points:

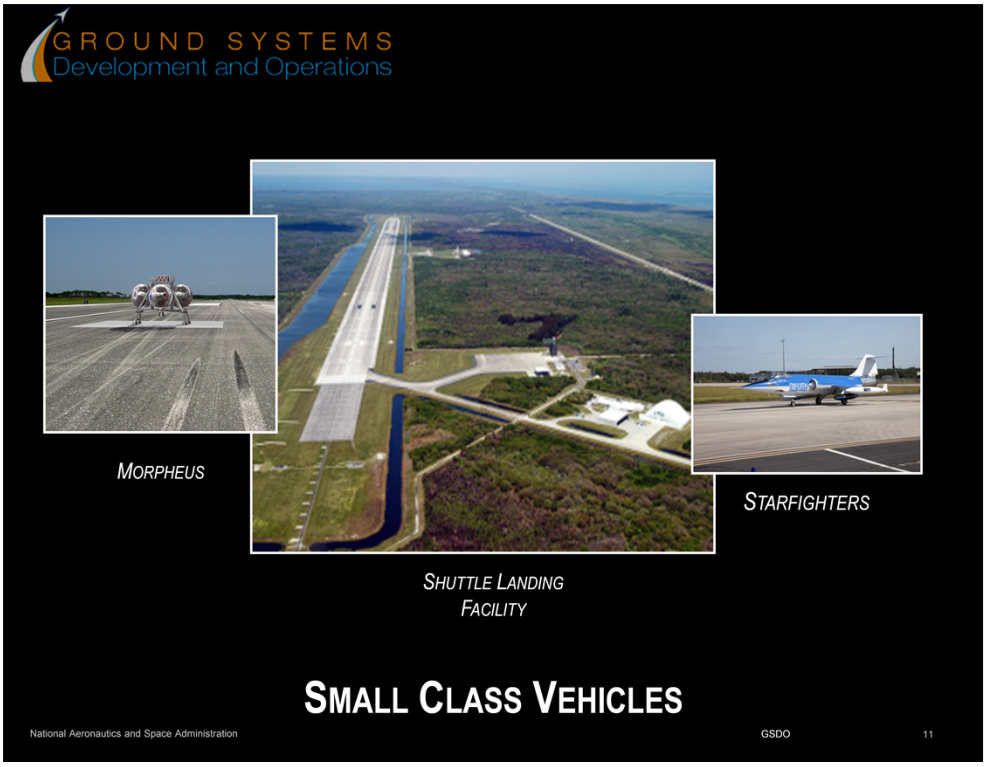
- The Crawler – Transporters (CT) lift and carry the mobile launcher or Mobile Launch Platform, with and without the vehicle, to and from the launch pad.
- The CT travels at a speed of 1 mile per hour on its trip to and from the launch pad and it takes around 8 hours each way for the trip.
- In March of 2012, a new engine and generator were installed inside crawler-transporter 2 (CT-2). The Apollo era diesel engines were removed. Work continues in high bay 2 to upgrade CT-2 so that it can carry NASA's Space Launch System heavy-lift rocket, which is under design, and new Orion spacecraft to the launch pad.

Background Info:

- CTs have carried the load of taking rockets and spacecraft to the launch pad for more than 40 years at NASA's Kennedy Space Center. The Crawler is 131 feet long and 114 feet wide.
- KSC has 2 Crawler Transporters (CT-1 and CT-2).
- They are powered by locomotive and large electrical power generator engines.
- Each crawler-way is 7 ft. (2 m) deep and covered with Alabama and Tennessee river rock to distribute the imense load of the CT, ML/MLP and the launch vehicle.
- It has an overall weight of 6.3 million pounds, and the capability to support a load of 12.6 million pounds.
- Each CT has 4 trucks (one in each corner) powered by 4 traction motors producing 375 hp each. There are a total of 16 traction motors producing 6000 hp for the Crawler.

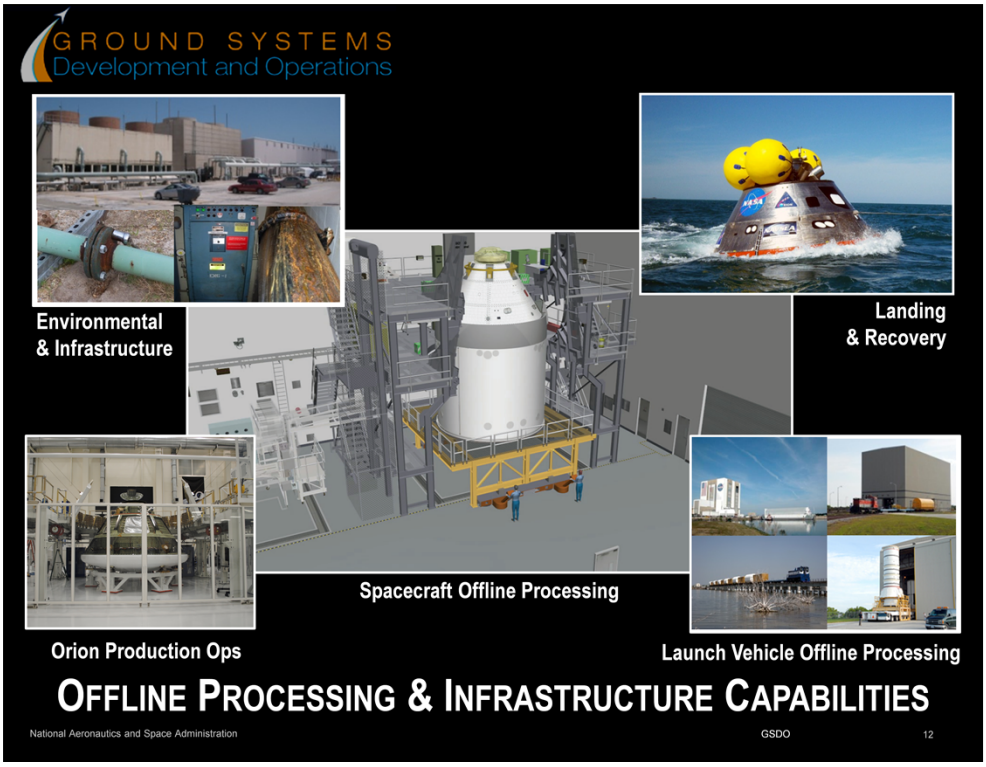
- In anticipation of the greater loads accompanying SLS, modifications are being made to one of the CTs to handle the additional weight as well as improve reliability and supportability.
    - Top left: CT making the trip back from Pad A.
    - Bottom left: Workers upgrade generator in CT-2
    - Top right: Both CTs at the Crawler Yard.
    - Bottom right: Overhead view of a CT.

    - For more info check: http://www.nasa.gov/pdf/639966main_20120425_Crawler%20Transporters.pdf



Key Points:

- Small class vehicles include experimental vehicles, suborbital vehicles, small orbital vehicles, or those with horizontal takeoff/horizontal landing.
- GSDO provides analysis and systems engineering support for small class vehicle integration and operations at KSC facilities.

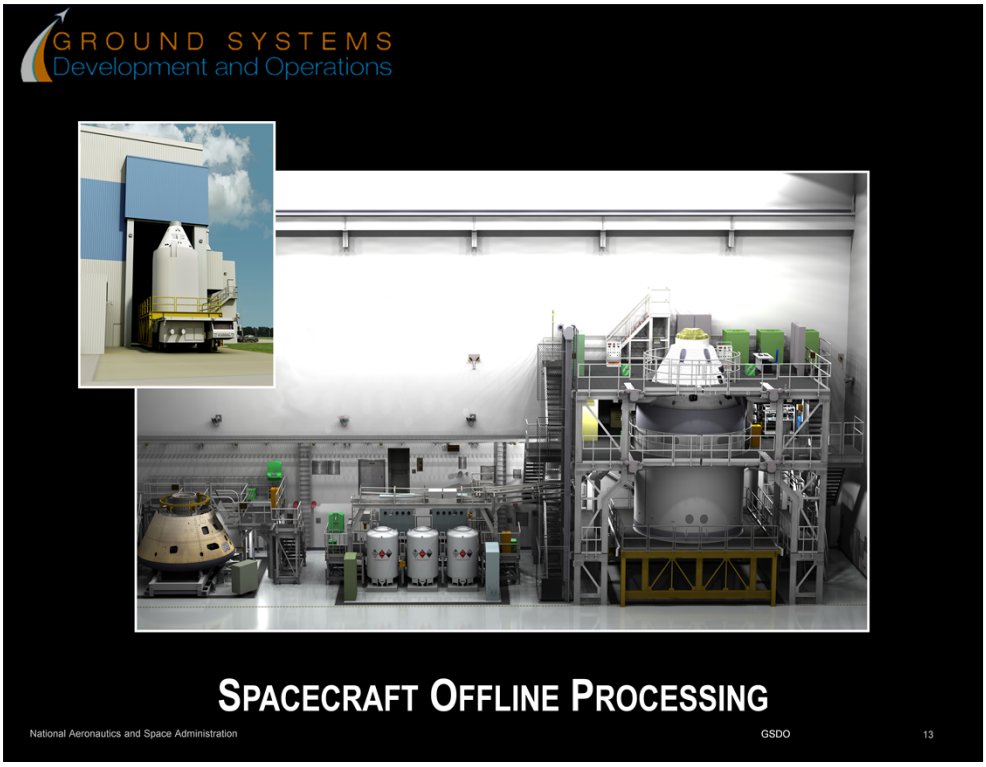


Key Points:

- The Offline Processing and Integration team will develop ways to handle the Orion spacecraft, rocket stages and launch abort system before they are all assembled into one vehicle.

Background Info:

- Center Image: The Orion Crew Module/Service Module sits in the Multi Payload Processing Facility work stand, preparing to be fueled for flight.



Key Points:

- Spacecraft Offline Processing team prepares the spacecraft for its mission by loading propellants and other commodities prior to installation onto the launch vehicle.

Background Info:

- Photo on Left: Once the Crew Module is put on top of the Service Module they are transferred to the MPPF (Multi – Payload Processing Facility). Photo shows the Orion Crew Module (CM) and Service Module (SM) leaving the MPPF, after processing.
- Photo on Right: Orion Crew Module (CM) and Service Module (SM) are brought in and prepared for launch in one of three processing bays. On the left, the photo shows the Crew Module being de-serviced after it has been recovered. On the right, the Orion “Short Stack” is serviced with propellants and other commodities in preparation for launch. The center bay is shown with mobile propellant storage tanks.

Key Points:

- Launch Vehicle Offline Processing primarily involves preparing components of the solid rocket boosters, Core Stage, and Cryogenic Propulsion Stage. It also involves future payload encapsulation and other vehicle processing needs prior to stacking in the VAB.

Background Info:

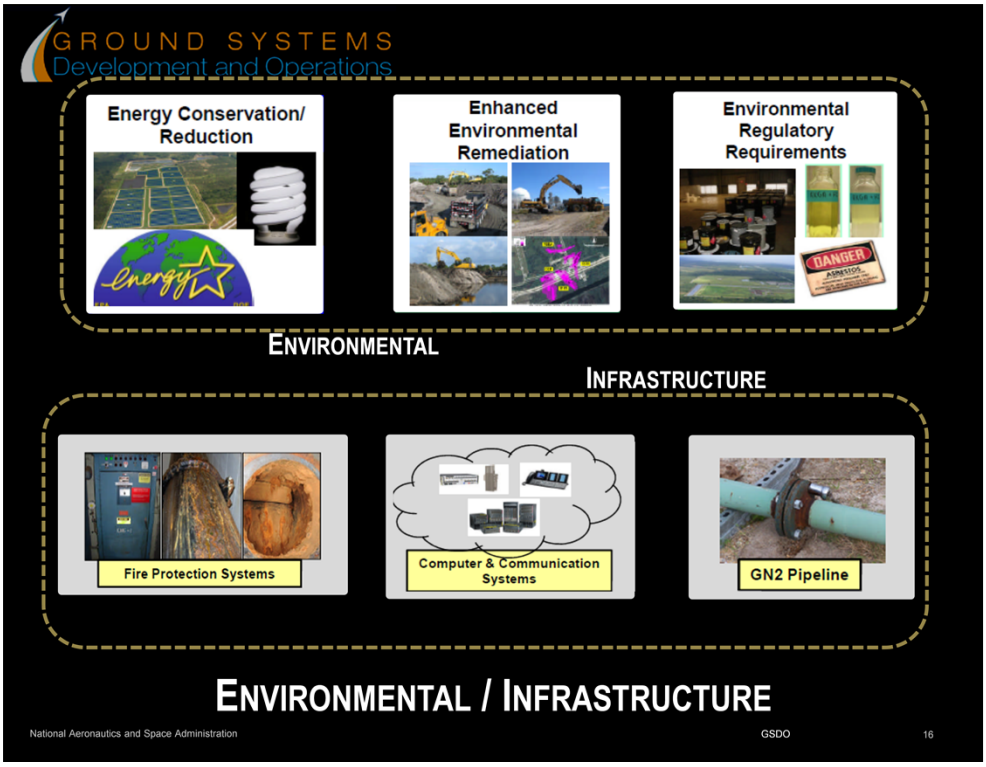
- Upper Left Photo: The solid rocket boosters (also called SRBs) arrive in the horizontal position in several segments on rail cars.
- Center Photo: Each Solid Rocket Motor (SRM) segment is removed from the rail car and rotated to the vertical in the Rotation & Processing Building.
- Bottom Left Photo: One of these segments is shown here assembled with the SRB Aft Skirt and rocket nozzle, ready for assembly onto the Mobile Launcher in the VAB. The segments are transported to the VAB (Vehicle Assembly Building) where they are lifted and stacked on top of each other on the Mobile Launcher to form the 2 sets of SRBs. Each SRB consists of 5 solid rocket motor segments.
- Top Right Photo: Concept image of Interim Cryogenic Propulsion Stage (ICPS) on a vertical transporter in the VAB.
- Bottom Right Photo: Concept image of SLS core stage sitting on a transporter in the VAB.
- If the heat energy created by the two SRBs could be converted to electric power, they would

produce enough power to supply 92,000 homes for a full day given a 2 minute firing.

- Each SRB burns 5 tons of propellant per second.
- Payload encapsulation is the process that provides a protective housing (outer cover) for the intended cargo.

Key Points:

- Recovery occurs in the Pacific Ocean, with a team led by NASA, using DoD assets.
- The ship pictured on the right is a Naval well-deck vessel which transports the spacecraft back to port.
- The people in this photo are attaching a flotation collar and a sea anchor, both of which help stabilize the spacecraft in the water.

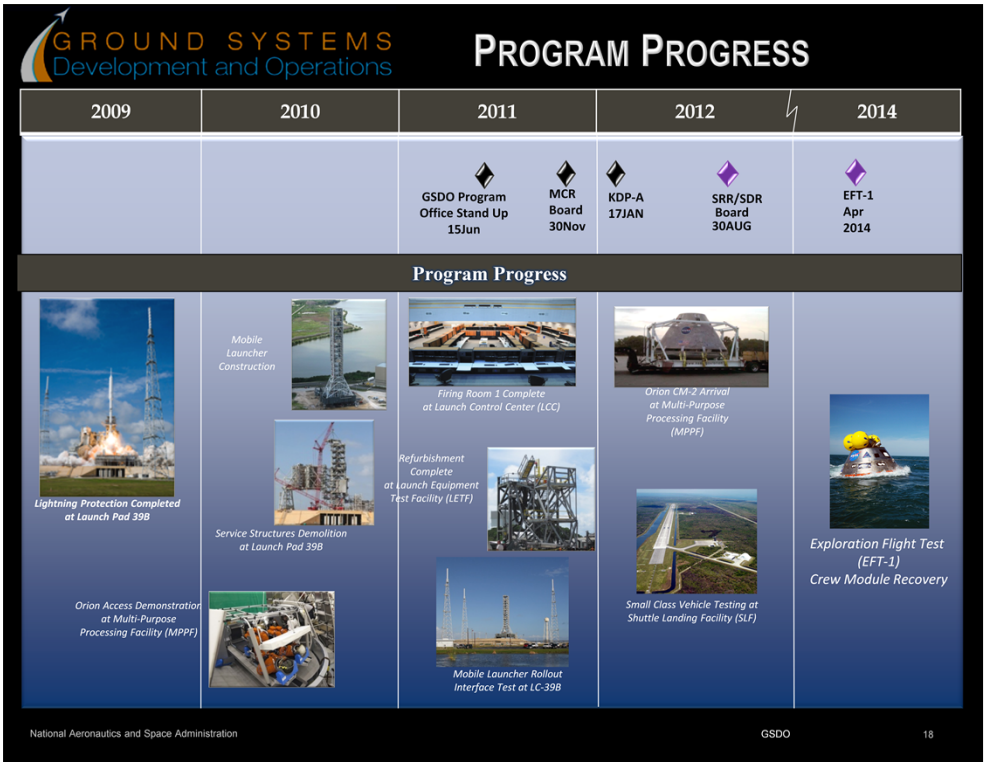


Key Points:

- The Environmental element team provides SLS and commercial launch programs a fully permitted environmental launch facility with unencumbered land and energy, operations and maintenance savings opportunities.
- The Infrastructure element team focuses on improvements and enhancements of infrastructure systems critical to payload processing and launch operations.

Key Points:

- The **Command Control Communications and Range systems** team is creating systems that can handle several different kinds of spacecraft and rockets. The team will use computers, antennas and software meant to reduce the need for a large launch team.



Key Points:

KSC projects and activities between 2009 and the start of GSDO in 2011 provided a head start, which has advanced GSDO further than is typical for a program in its infancy.

Background info:

2009

On January 4th a huge crane lifted the remaining steel structure and fiberglass mast from the ground and hoisted it up, completing a 600-foot-tall lightning tower that now sits on the east side of the launch pad. A system of overhead wires attached to the mast of each tower will provide the launch vehicles a blanket of protection from lightning strikes, while cameras installed on each tower will record any strikes. The towers also will house weather stations at four elevations to measure wind speed, wind direction, temperature and humidity.

2010

Construction of the ML structure, completed in August 2010, took about two years. The launcher is designed to support the assembly, testing, check out and servicing of the rocket, as well as transfer it to the pad and provide the platform from which it will launch.

The Fixed Service Structure/Rotating Service Structure (FSS/RSS) demolition began in late September 2010 and was finished a year latter in September 2011.

In support of a future Multi-Purpose Crew Vehicle, several demonstrations were performed. The

team participated in the Orion Landing and Recovery Ground Support Equipment (GSE) Demonstration at KSC, a proof-of-concept GSE to demonstrate general handling and towing operations of the Crew Module (CM) in the event of contingency landing and recovery operations. The demonstration included participation from flight crew, fire and rescue personnel, and ground operations closeout crew to evaluate potential sequences for nominal ingress and contingency egress.

2011

In January, The Launch Control System (LCS) team completed the installation of 60 consoles and 15 command workstation/support workstation pairs to complete Phase 1 (15 consoles, no communication) of the LCC Firing Room 1 Console Power Distribution Chassis Installation.

A four-year comprehensive upgrade to the Launch Equipment Test Facility was completed to make sure the testing ground remains at the top of the support system testing pyramid. The LETF plays a vital role in proof-of-concept testing, prototype testing and operations support. Part of the refurbishment process was to equip the facility with a 600-ton test fixture used for tension and compression testing, a water flow test loop that tests valves, pumps and flow meters, two launch simulation towers and two 15,000-gallon cryogenic towers. Perhaps most impressive is the new Vehicle Motion Simulator, or VMS, which simulates all of the movements a vehicle could experience from rollout to launch.

The team supported the kickoff of the Mobile Launcher/Launch Complex 39B (LC39B) Trade that evaluated the feasibility of several low-cost ground systems configurations needed to support the heavy lift launch vehicle.

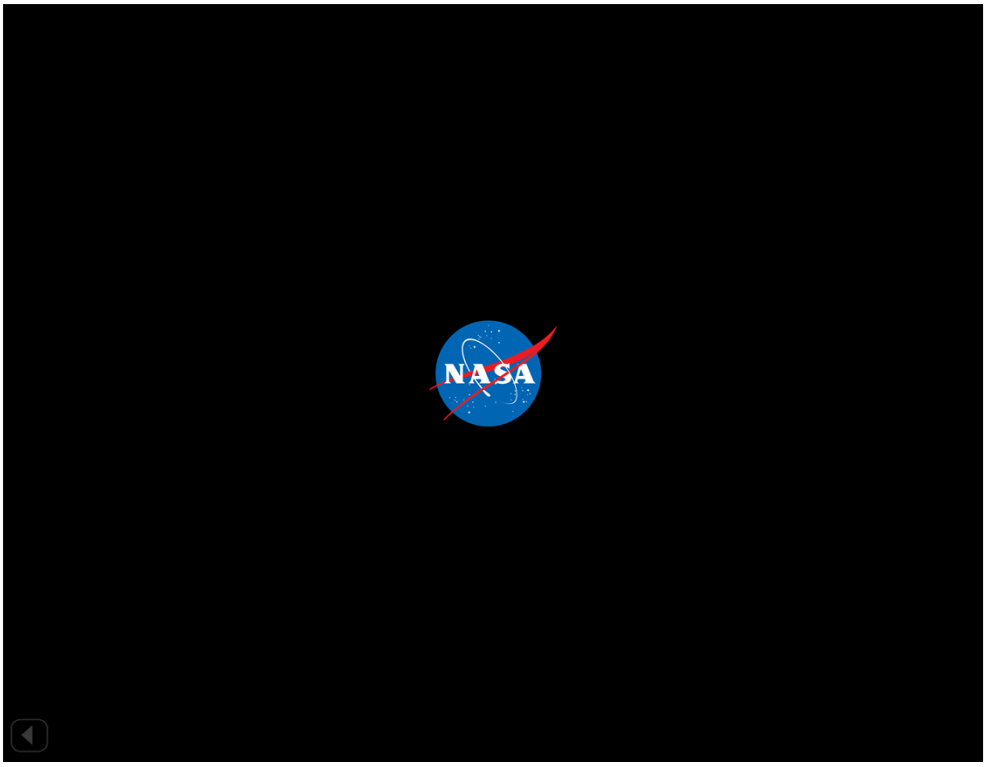
2012

The Orion Ground Test Vehicle arrived at NASA’s Kennedy Space Center (KSC) in Florida on Saturday, April 21. The vehicle traveled more than 1,800 miles from Lockheed Martin's Waterton Facility near Denver where it successfully completed a series of rigorous tests that simulated launch and spaceflight environments. Orion will be fully assembled and integrated on site at KSC, a new capability that provides significant time and cost savings.

The area near the runway (SLF) will be turned into a field of hazards as part of the next phase of tests for the Project Morpheus lander, which integrates technologies that someday could be used to build future spacecraft destined for asteroids, Mars or the moon. Morpheus is a small class vehicle designed, developed, manufactured and operated by NASA. This vertical test bed vehicle demonstrates new green propellant propulsion systems and autonomous landing and hazard detection technology. The lander has been undergoing testing at NASA's Johnson Space Center in Houston for almost a year in preparation for its first free flight. During flight testing, it will rise almost 100 feet into the air, fly 100 feet laterally, and then land safely.

Key Points:

- GSDO is supporting the President's direction for space exploration, by developing ground systems that support the new Space Launch System (SLS) launch vehicle and Orion Multi-Purpose Crew Vehicle (MPCV) spacecraft, as well as other government and commercial companies.
- This marks a new era in space exploration, to replace the Space Shuttle program.
- GSDO takes input from various stakeholders, including SLS, MPCV, Launch Services, Commercial Crew, the Air Force, and Space Florida.
- These inputs are used to develop a launch complex that supports both government and commercial users.



The End.